

# Cloud-resolving models: How good are they and what can they do for you?

Ann Fridlind

*in collaboration with*

Andy Ackerman

Bastiaan van Dierenhoven

*with support from*

NASA and DOE ARM Programs

NASA Advanced Supercomputing Division

DOE National Energy Research Scientific Computing Center

NASA GISS • 28 April 2008

# What can they do for you?

- predict the weather?
- predict cloud-climate interactions?
- serve as tools for studying and improving weather and climate forecasts?
- predict cloud effects on aerosols?
- predict aerosol effects on clouds?
- predict cloud effects on tracer transport?

# How good are they?

- clouds remain poorly resolved
- many processes are poorly parameterized, not understood, or missing
- results generally unconstrained with even basic field data
- nonetheless often used to replace real data

# Dynamics framework

- large-eddy simulation [Stevens and Bretherton, 1997]
- dynamic Smagorinsky subgrid model [Kirkpatrick et al., 2006]
- doubly periodic, 250-m sponge layer at top
- $64 \times 64 \times 96$  mesh,  $50 \text{ m} \times 20 \text{ m}$  uniform grid
- specified SST, similarity sensible and latent heat fluxes
- specified advective flux and subsidence profiles
- 2-stream radiative transfer, 44 wavelength bands [Toon et al., 1989]

# Size-resolved microphysics

- aerosols: 20 bins, 10 nm–1  $\mu\text{m}$  diameter
- liquid: 20 bins, 2  $\mu\text{m}$ –2 mm
- ice: 20 bins, 2  $\mu\text{m}$ –5 mm
- ice nuclei: 10 bins, most to least easily nucleated
- = 90 variables

# Microphysical processes

- drop activation, condensation/evaporation
- gravitational collection [Hall, 1980; Beard and Ochs, 1984]
- particle sedimentation
- homogeneous ice formation
- heterogeneous ice formation (deposition/condensation, immersion, contact modes)
- phoretic scavenging [Young, 1974],  $0.5 \mu\text{m}$  diameter ice nuclei [Rogers et al., 2001]
- deposition/sublimation
- multiplication

# Long-lived stratocumulus deck

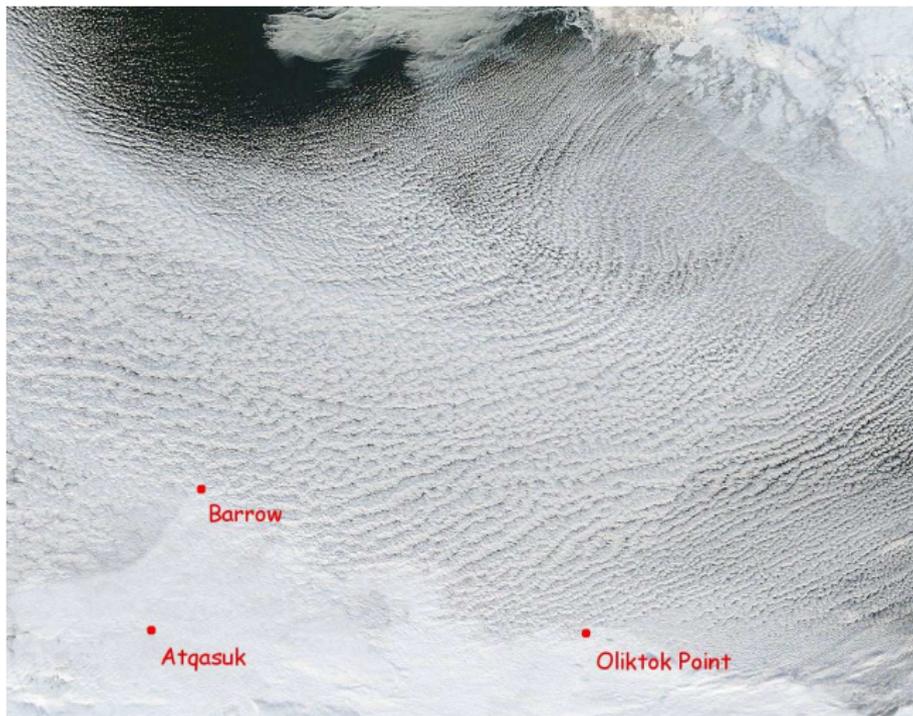
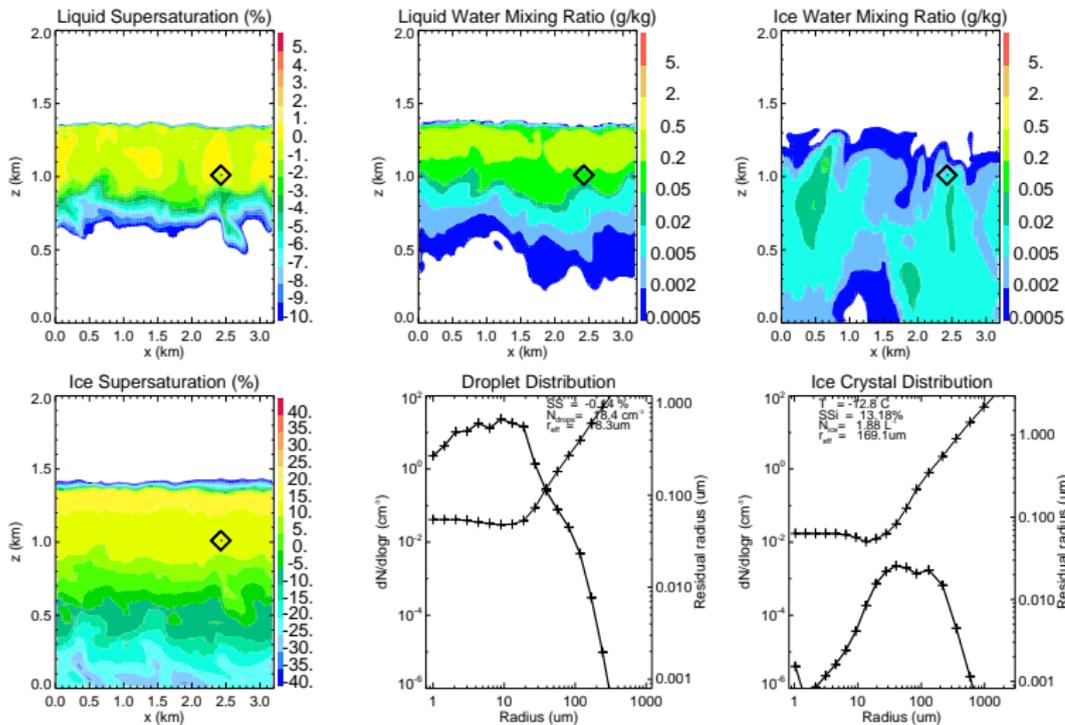


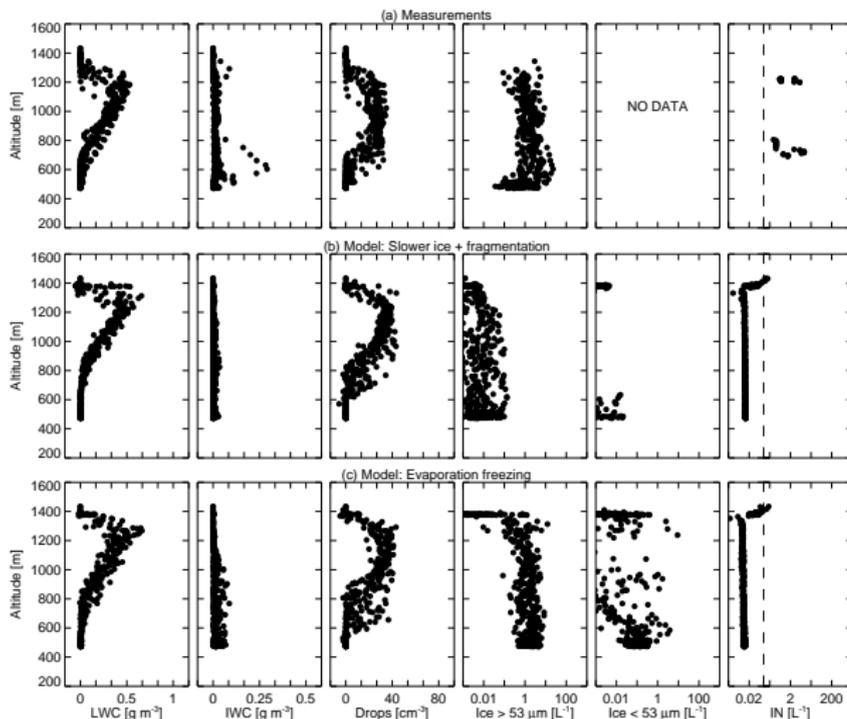
Image source: AVHRR, Pennsylvania State University M-PACE website

## DHARMA results



## Mixed-Phase Arctic Cloud Experiment (M-PACE)

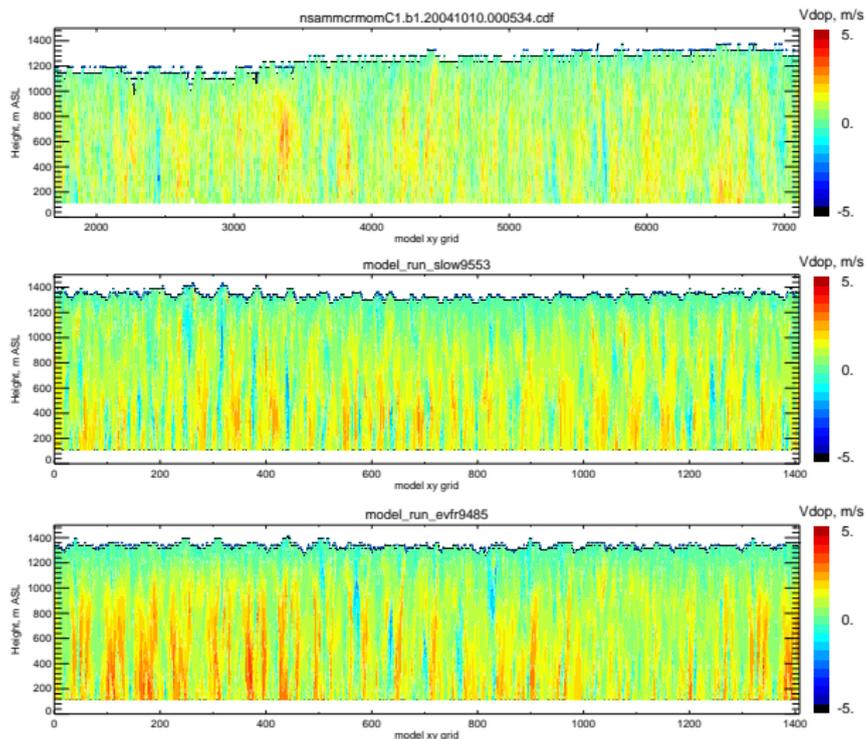
## In Situ Aircraft Measurements



Source: Fridlind, Ackerman, et al. [JGR, 2007]

## Mixed-Phase Arctic Cloud Experiment (M-PACE)

## MMCR Doppler Velocity



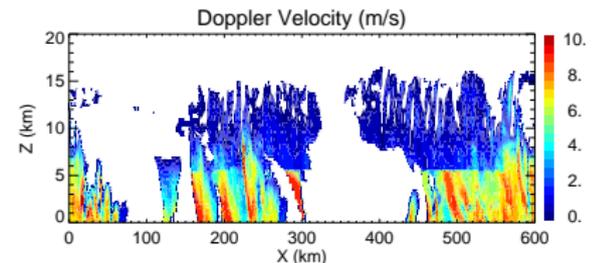
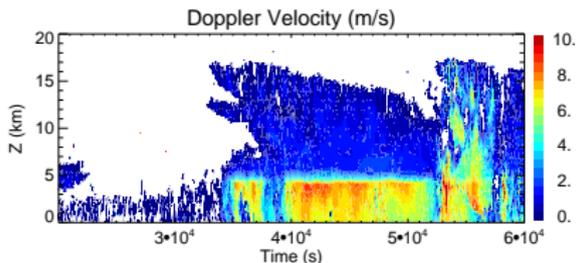
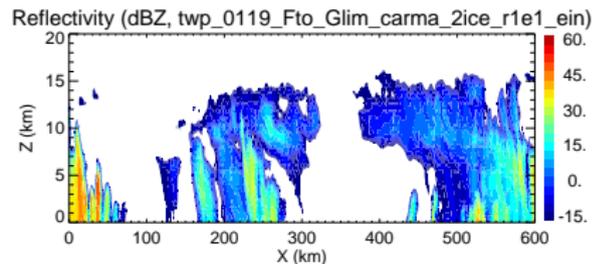
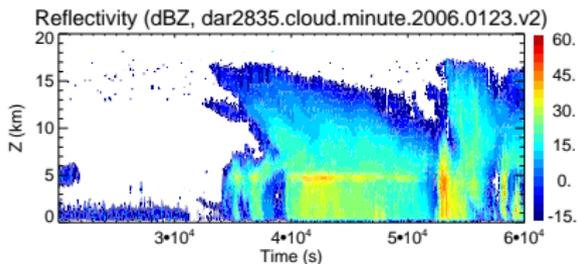
Acknowledgments: DOE ARM data archive, QuickBeam radar simulator [Haynes et al., BAMS, 2007]





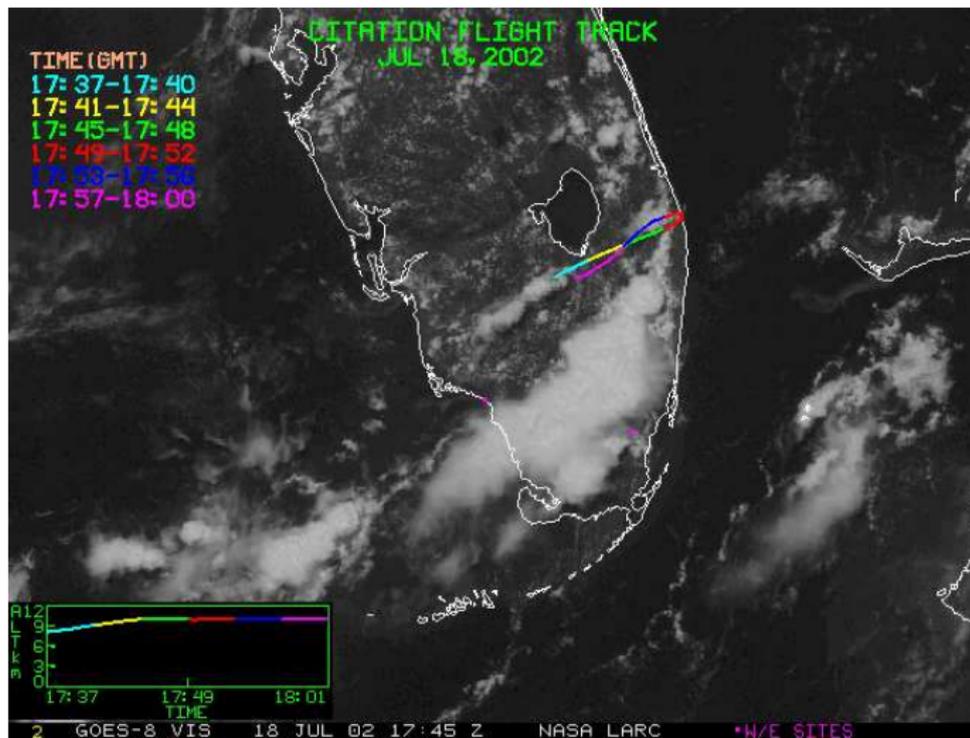
Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

# S-Band Reflectivity + Doppler Velocity

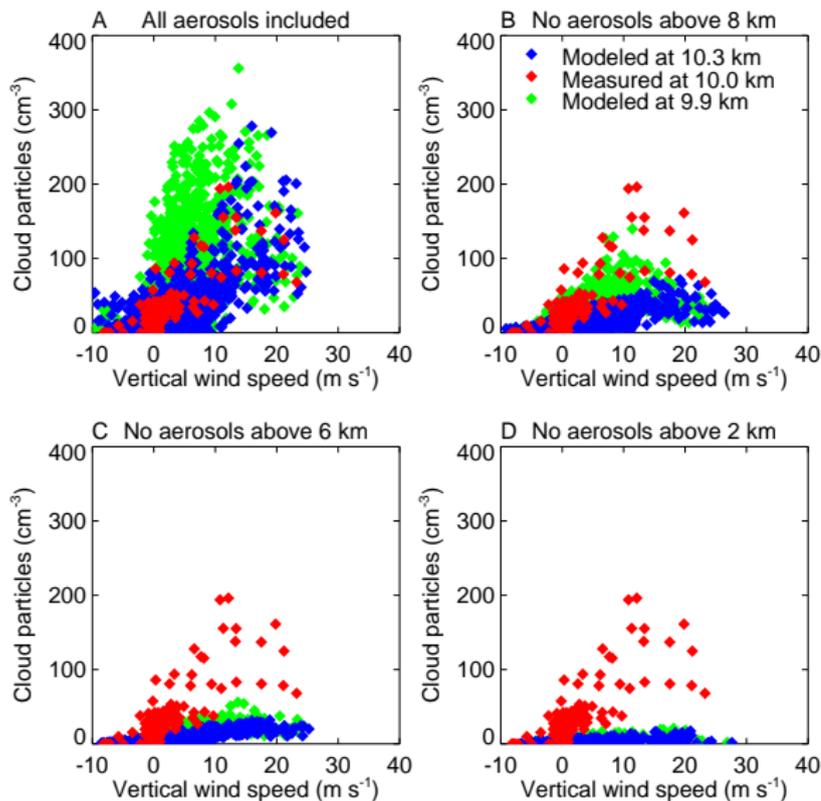


Acknowledgments: DOE ARM data archive, Christopher Williams (NOAA)

# 25-m/s updraft penetration



# 25-m/s updraft penetration



## Funded Projects FY08–FY10

- *Understanding tropical cumulonimbus clouds: Aerosols, updrafts, precipitation, ice crystal size, and climate* (NASA ACRM), Fridlind/Ackerman/Del Genio
- *Arctic stratus and tropical deep convection: Integrating measurements and simulations* (DOE ARM), Fridlind/Ackerman/Koch with collaborators Del Genio/Menon/Comstock/Williams/Eloranta/DeBoer
- Need for full-time post-doc on GCM side